Cassini: Mission to Saturn and Titan

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The Cassini Mission to Saturn and Titan represents an important step in the exploration of the outer planets. It will expand on the flyby encounters of Pioneer and Voyager and parallel the detailed exploration of the Jupiter system to be accomplished by the Galileo Mission. By continuing the study of the two giant planets and enabling detailed comparisons of their structure and behavior, Cassini will provide a tremendous insight into the formation and evolution of the solar system. In addition, by virtue of its focus on the Saturnian satellite Titan, Cassini will return detailed data on an environment whose atmospheric chemistry may resemble that of the primitive Earth.

The Cassini Mission, named after the Italian astronomer Domenico Cassini who first discovered structure in Saturn's rings, will consist of two major parts. The first will be the delivery of a probe into the atmosphere of

Titan for sampling and detailed chemical and physical analysis. This will be followed by a 4-year orbital tour of all parts of the Saturn system, including numerous flybys of Titan and the "icy" satellites. NASA will build the orbiter as the second spacecraft in its Mariner Mark II series; these are modular spacecraft designed for reduced-cost exploration of the outer planets and small bodies. The European Space Agency (ESA) will provide the Titan probe, which will be integrated with the orbiter. The Mission will be launched in April 1996, on a Titan IV/Centaur expendable launch vehicle, and will arrive at Saturn in October 2002. Delivery of the probe to Titan will occur in January 2003, and the Mission will last until the end of the Saturn tour in September 2006.

Cassini has been the subject of a joint NASA/ESA Technical Assessment since 1984. A joint U.S./European science working group led by D. Gautier, W. Ip, and T. Owen has formulated detailed scientific objectives and a strawman instrument payload. At the same time, U.S. and European technical study teams have developed corresponding mission and spacecraft designs. Cassini is a candidate for a NASA New

Start in FY 1990 (as part of the Mariner Mark II program, in combination with the Comet Rendezvous Asteroid Flyby Mission) while the Titan probe is a candidate for selection by ESA in November 1988. The instrument payload of the orbiter and the probe will comprise both U.S. and European experiments; science selection is planned for December 1990.

This chapter provides an overview of the Cassini Mission and its scientific objectives. Particular attention will be paid to Titan and the Titan probe phase of the Mission, to emphasize the potential contribution to the study of exobiology. The information contained in this chapter was current at the time of its preparation in August 1988. Since then the Cassini Mission was approved by Congress and has evolved significantly. However, the description contained herein remains representative of the Mission, particularly with respect to exobiology issues. Please contact the CRAF/Cassini project office at the Jet Propulsion Laboratory for further information.

Science Objectives and Payload

The model payloads of the probe and the orbiter are shown in table 13-1. The scientific objectives can be divided into five categories: Titan, Saturn, rings, icy satellites, and magnetospheres. The key area of interest to exobiologists is Titan; the other four scientific categories will be discussed briefly to provide a comprehensive overview of the Cassini Mission.

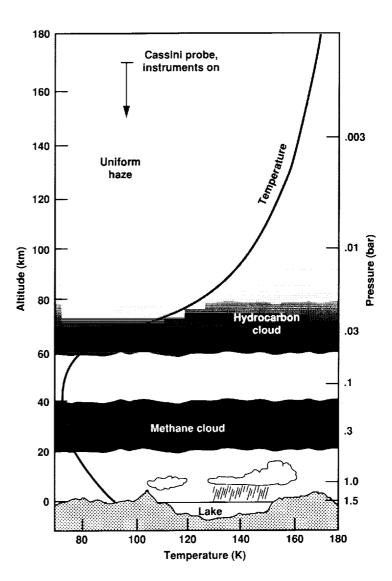| Table 13-1: Model Scientific Payload	
Orbiter	Probe
Ultraviolet Spectrometer/ Imager	Descent Imager/Spectral Radiometer
Mid-Far Infrared Spectrometer	Lightning/Radio Wave Detector
Microwave Radiometer/ Spectrometer	Laser Spectrometer/Particle Size
High-Speed Photometer	Gas Chromatograph/Mass Spectrometer
Imaging Radar/Radar Sounder	Aerosol Collector/Pyrolyzer
Radio Science	Atmospheric Structure Instrument
Ion/Neutral Mass Spectrometer	Surface Science Package
Wide and Narrow Angle Cameras	Science Using Probe Engineering Subsystems
Near-Infrared Spectrometer	– Radar Altimeter
Ion Analyzer/Langmuir Probe	– Doppler Wind Experiment
Dust Analyzer	
Energetic Gas/Hot Plasma Detector	
Plasma/Radio Wave Spectrometer	
Plasma Spectrometer	
Magnetometer	

Titan

Titan was discovered in 1655 by the Dutch astronomer Christiaan Huygens, who also first postulated the existence of Saturn's rings. Titan is by far the largest Saturnian satellite; in fact, with the exception of Jupiter's moon Ganymede, it is the largest satellite in the solar system. It is also the only satellite known to possess a dense atmosphere, and it is this atmosphere that makes Titan such an important target for exploration. While its size and atmospheric density might stimulate comparisons to the terrestrial planets, at such a great distance from the Sun, Titan is much colder and richer in ices. The surface temperature is about 95 K, which is a few degrees above the melting point of methane.

It has been postulated that lakes or oceans of liquid methane or other hydrocarbons might dominate the surface, and that dense methane clouds exist in the lower atmosphere below the visible orange haze. Figure 13-1 shows a sketch of this model along with an atmospheric temperature profile. Also indicated is the altitude at which the Cassini probe will begin to sample the atmosphere. For reference, table 13-2 presents the current estimates of some of Titan's physical properties.

The presence of methane in Titan's atmosphere has been known since about 1944. It appears to be present in quantities sufficient to require continuous replenishment from methane "lakes" or subsurface degassing. The uniform orange haze obscures any atmospheric structure; it is generally agreed that this haze is composed of condensed organic compounds including polyacetylenes and cyanide polymers. About 10 such organic compounds have been identified, all of which can be derived by photochemistry of a nitrogen-methane mixture.

Much of the detailed information about Titan's atmosphere has been extracted from Voyager flyby data. One of the most important results was the detection of three nitriles, HCN, HC_3N, and C_2N_2. Laboratory experiments have shown that HCN is a precursor of purines (adenine in particular), which are among the building blocks of nucleic acids on Earth. Similarly, HC_3N leads to pyrimidines, which are also present in nucleic acids. Thus, some of the key outstanding issues are the abundances and distributions of gaseous nitriles in Titan's upper atmosphere, the degree of complexity these compounds have achieved, and the processes and pathways for producing these components.

Titan's stratosphere is known to contain hydrocarbons, nitriles, and oxygen-bearing compounds, while the troposphere contains CO, Ar, N_2, H_2, and CH_4. The low tropopause temperature of about 70 K, as shown in figure 13-1,

Table 13-2: Titan Physical Characteristics

Radius	2575 km
Mass	1.83 lunar masses
Rotational period	16 days
Orbital radius	20 Saturn radii
Orbital period	16 days

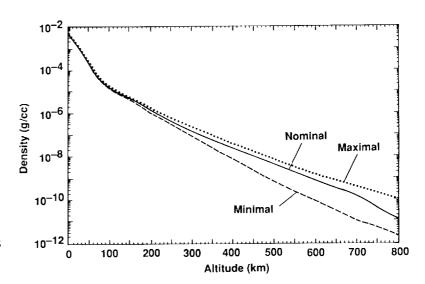Figure 13-1. Titan's lower atmosphere.

acts as a cold trap for most gases and should limit their amounts in the stratosphere unless they are formed there. Thus, it appears that the stratospheric compounds are formed at this level by complex photochemistry. Condensation of these and other gases forms the thick smog-like haze and induces a greenhouse effect that is responsible for Titan's somewhat elevated surface temperature. Of critical importance to an overall understanding of Titan's atmospheric chemistry is the determination of the relative abundances of the various constituents as a function of altitude. This will serve to test the theories of atmospheric origin, and will help to determine what condensed materials should have been deposited on the surface.

While figure 13-1 shows a temperature profile in the lower atmosphere, the structure of this profile between 200 and 1500 km altitude is unknown. In addition, it has been predicted that strong zonal winds may be present, but their magnitude and direction are uncertain. These are fundamental questions which will be answered by the Titan Probe Mission; however, design of the Mission itself

requires that these quantities be modeled as accurately as possible. The Cassini Mission has adopted a particular model of Titan's atmosphere, known as the Hunten-Lellouch model, for the purposes of mission and science planning. One quantity of importance to the probe design, for example, is the atmospheric density as a function of altitude, since this will determine the probe's rate of descent. Figure 13-2 shows the density predicted by the Hunten-Lellouch model.

The Cassini probe will begin sampling the atmosphere and transmitting data at an altitude of about 170 kilometers. The descent from this level to the surface will last approximately 2.5 hours. The Gas Chromatograph will measure the vertical distribution of hydrocarbons and nitriles and detect organics in gaseous form, and the Mass Spectrometer will measure elemental and isotopic abundances as a function of altitude. The Aerosol Collector and Pyrolyzer will detect condensed organics.

Figure 13-2. Hunten-Lellouch model atmosphere.

The Probe Infrared Laser Spectrometer will use a set of tunable diode lasers at selected mid-infrared wavelengths to measure volume mixing ratios for many organic compounds; it will also have a nephelometer capability to discern particle size distribution in the aerosol and cloud layers. A Descent Imager will reveal any cloud structure and atmospheric circulation. In addition, the doppler shift in the probe radio transmissions will be relayed to Earth and carefully analyzed to provide information on wind direction and magnitude during the descent.

Because of the thick haze layer, the surface of Titan has never been observed; its precise nature will remain unclear until the Cassini probe is able to resolve it. Although it is not a probe design requirement, it is expected that the probe will survive the surface impact. Provided that its radio antenna remains pointed in the general direction of the overflying Mariner Mark II spacecraft, the probe should be able to transmit several minutes of data from the surface. An accelerometer will measure the force of impact to provide some insight into the surface state, and this data will be transmitted immedi-

ately. A simple surface sample collector, such as a heated inlet, will allow a fast mass spectroscopic analysis of the surface material. Such measurements can be completed and transmitted to the orbiter in approximately 2 minutes; the radio relay link will be designed so that the orbiter will be in view of the probe for at least that long after the nominal impact time. A dedicated surface science package on the probe may consist of a refractometer to measure the index of refraction of a possible liquid surface, an X-ray fluorescence spectrometer to determine elemental composition of a solid surface, and an acoustic sounder to determine the density of the surface material.

During the 4-year Saturn orbital tour, the Mariner Mark II spacecraft will make about 40 close flybys of Titan. Many of the flyby altitudes will be below about 3000 km, and these are most useful for the radar instrument. This will allow the spacecraft to "see" Titan's surface through the orange haze; most of the surface will be mapped in this way, to establish its state (solid or liquid), topography, and structure (through radar sounding). Infrared spectra will provide vertical distributions of nitriles and other hydrocarbons on a global scale, to supplement the probe measurements.

Aeronomy instruments will sense the upper atmosphere during the closer flybys, which may be as low as 800 km altitude. The Ion/ Neutral Mass Spectrometer will provide compositional information, and the Langmuir Probe will measure ion and electron temperatures and densities. Radio, solar, and stellar occultations will be used extensively to measure atmospheric abundances and physical structure.

The combination of a probe descent and multiple flybys will yield a tremendous amount of new information on the structure and behavior of Titan. The data will be analyzed by scientists from a wide variety of disciplines, including exobiology, since Titan should be an excellent natural laboratory for studying chemical processes that may have been important on the pre-biotic Earth.

Saturn

While Saturn has been observed from Earth for centuries, the state of knowledge about the planet was greatly enhanced by the Pioneer and Voyager flybys. For example, Saturn has been found to have complex atmospheric chemistry and wind patterns, an unexpectedly strong internal heat source, and a hydrogen-to-helium ratio that is significantly higher than that of Jupiter. Models have been advanced to explain these and other phenomena; validation and enhancement of these models will be made possible through detailed, long-term study by the Cassini spacecraft. A comparison of species abundance and isotopic ratio data with similar measurements by the Galileo Mission at Jupiter will advance our understanding of the differences between the two planets. This will allow more precise modeling of the composition of the pre-solar nebula, which is vital to an understanding of solar system formation and evolution.

Throughout the orbital tour, Saturn will be observed with remote-sensing instruments from a wide variety of orbits and lighting conditions. The gravitational field will be accurately mapped, and together with radio occultation data on the planet's shape, this will enable accurate modeling of the interior structure. Occultations and infrared observations will determine atmospheric structure and abundances. Determination of the global energy balance and ammonia abundance are major goals. Long-term observations of the atmosphere will permit precise modeling of circulation patterns, which is vital to an understanding of Saturn's structure.

Rings

Saturn's ring system is one of four in the outer solar system, and it is by far the most extensive and complex. The rings are composed of particles ranging in size from tiny pebbles to large boulders, including a sprinkling of fine dust. The ring particles are composed mostly of icy material, but contain impurities of unknown origin. The amount of these impurities seems to vary between the different rings.

Voyager revealed a ring system of unexpected structural complexity and variety. Images provided structural detail throughout the rings on scales as small as a few kilometers. Detailed structure, with 100-meter resolution, was visible in stellar and radio occultation data. The ring structure is driven in part by spiral density waves and spiral bending waves, and by the dynamical interactions of small moonlets with the ring particles. Other interesting structures include clumpy or "braided" rings as well as "spokes" that appear to be electrostatically charged particles levitated above the ring plane.

The Cassini orbiter will provide extensive imaging and occultation coverage of the ring system, so that the spatial and temporal variations in structure can be observed. A search for additional moonlets will be important to an understanding of ring dynamics. The composition of individual particles will be determined by reflectance spectrometry and thermal radiometry. Such a complete understanding of the planetary ring structure is required before the fundamental questions of ring age and formation can be answered.

Icy Satellites

There are eight major Saturnian satellites other than Titan; several of the larger satellites, in fact, were discovered by Domenico Cassini himself. In addition, there are several other smaller satellites and an undetermined number of moonlets near the main rings. As a class, these are termed the "icy" satellites, since they are composed primarily of water ice with varying amounts of a darker material probably similar to that found in primitive meteorites. Voyager and Pioneer showed these satellites to be remarkably diverse and to exhibit evolutionary histories unexpected for their small sizes. There are suggestions that the system has been through periods of collision and fragmentation, and that the smooth surfaces of some of the bodies imply a mechanism for internal heating and resurfacing. Indications of recent activity were present in the Voyager data and possibly corroborate the theory that the small particles of Saturn's diffuse E-ring are actually expelled by the satellite Enceladus through some unknown mechanism. Enceladus is very bright (in fact, it is the most reflective body in the Solar System), which is consistent with a surface of geologically young material.

Iapetus has a coating of dark material on its leading hemisphere which is suggestive of carbon-rich organic matter. The source of this material is unknown, and further analysis may help to elucidate the relationship among icy satellites, comets, and primitive carbonaceous meteorites. This may have important implications for the theories that invoke comets and meteorites for the initial delivery of organic molecules to the inner solar system. Exploration of Iapetus is thus given a high priority in the Cassini Mission; two very close flybys of this satellite will be included as a part of the orbital tour.

Each of the main icy satellites will be encountered several times during the Cassini Mission. Most of the flybys will be at tens of thousands of kilometers, but closer flybys of Enceladus and Dione, as well as Iapetus, are planned. Imaging, multispectral studies, and other remote sensing experiments will be active during each flyby. This will allow characterization of the surface topographies and compositions, so that the geological history of each satellite can be inferred.
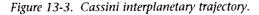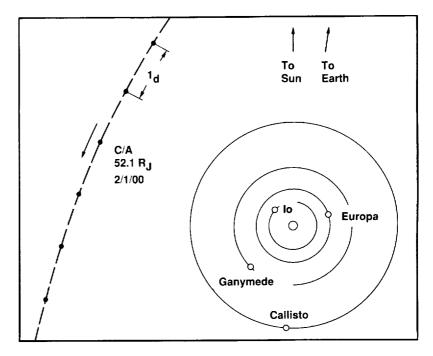
Magnetospheres

Saturn, unlike Earth, has a magnetic dipole axis that is closely aligned with the planet spin axis. The axial symmetry of the internal magnetic field is unique among the planetary magnetic fields yet observed. However, strong periodic modulations of Saturn's radio emission imply that the surface fields are not axially symmetric. The plasma environment is not well understood, though it is known to be extremely complex and time-variable, and a strong interaction between the magnetosphere and the icy satellites has been observed. Because the dimensions of the magnetosphere vary with the strength of the solar wind, Titan is at times outside the magnetosphere and in the solar wind. Titan's solar wind interactions are thought to be intermediate between those of Venus and the comets.

To thoroughly characterize the magnetosphere, the Cassini orbits will cover a wide range of orbital inclinations. Near-polar orbits will provide a direct measurement of the energy deposition into the atmosphere and the subsequent auroral emissions, and will allow study of the so-called Saturn Kilometric

Radiation. Long-term observations will address the time variability of the phenomena. The Cassini plasma instruments will be on a turntable rotating at a constant 1 rpm, to provide the measurements with spatial detail. Cassini's capability for spatial and temporal resolution of the velocities of various components will place it at the forefront of planetary plasma physics.

Mission Design

The baseline Cassini interplanetary trajectory is illustrated in figure 13-3. Launch will be on April 8, 1996, using the Titan IV/Centaur launch vehicle. The fully fueled spacecraft mass will exceed the injection capability of the Titan IV/Centaur for direct trajectories to Saturn, so the
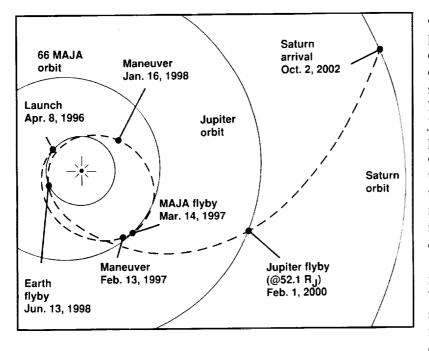
Figure 13-3. Cassini interplanetary trajectory.

Figure 13-4. Cassini Jupiter flyby.

closer approaches are not possible for the 1996 mission opportunity, so any close encounters with the Galilean satellites will be impossible. Nonetheless, significant Jupiter science can be accomplished during the flyby. For example, figure 13-5 shows the passage of the Cassini trajectory through the Jovian magnetotail. As the plot indicates, the Cassini spacecraft will spend nearly 130 days in this region. The relatively brief passages of Voyager 1 and Voyager 2 are shown for comparison. The flyby will thus allow mapping of the structure of the magnetotail in a previously unexplored region.
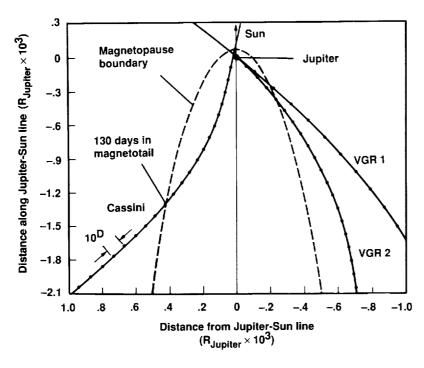
Cassini Mission must rely on a gravity-assist flyby of Earth about 2 years after launch, and an additional flyby of Jupiter about 20 months later. The proper Jupiter-Saturn phasing will be available for missions launching in 1995-1997 and will not recur until 2016.

With the required performance margins, the current estimates of launch vehicle capability and spacecraft mass result in a minimum flight time to Saturn of about 6.5 years. This includes an allowance for a flyby of the asteroid 66 Maja, as shown in figure 13-3. Saturn arrival is currently planned for October 2, 2002.

Jupiter Flyby

Jupiter's closest approach occurs on February 1, 2000, at 52.1 Jupiter radii, a distance at which the radiation environment will pose no threat to the Mariner Mark II spacecraft subsystems. Figure 13-4 shows the spacecraft trajectory and the Galilean satellites at the time of closest approach. The flyby radius is determined by the Jupiter-Saturn phasing and the trajectory's gravity assist requirements; significantly

Figure 13-5. Jupiter magnetotail passages.

Probe Entry and Data Relay

Several scientific and engineering requirements will constrain the selection of the probe's entry site. These are

1. Entry and descent on the day side of Titan;

2. Descent not more than 60° from the equator;

3. Entry favorable for doppler wind determination; and

4. Flightpath angle (at atmosphere interface) between –60 and –90°.

Figure 13-6 is a view of Titan as seen from the probe's approach trajectory, showing the allowed probe entry region.

The Saturn orbiter will be targeted to pass over (or near) the Titan probe entry point about 3 hours after probe entry. This time delay must be carefully chosen to ensure that the orbiter is properly positioned to receive and relay the probe data, including at least 2 minutes of data after the expected time of probe impact on Titan's surface. The total amount of data transmitted depends strongly on both the orbiter delay and the flyby distance. Thus the probe data relay
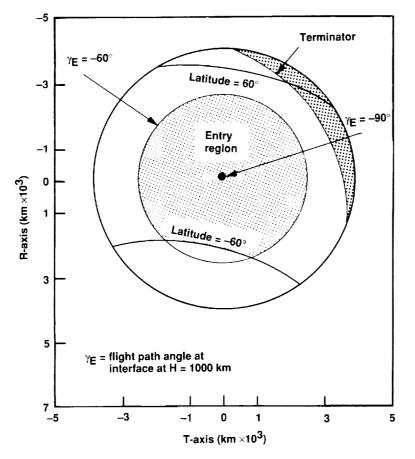
Saturn Orbit Insertion and Probe Delivery

Upon arrival at Saturn a "dual burn" orbit insertion strategy will be used to achieve the desired initial Saturn orbit. This strategy consists of an orbit insertion burn at periapsis (1.8 Saturn radii), which places the spacecraft into a 100-day Saturn orbit, and a periapse raise maneuver at apoapsis 50 days later. This will adjust the orbit to achieve the desired atmospheric entry conditions for the Titan probe. The probe will be released from the orbiter about 12 days before entry; the orbiter will then perform a maneuver to enable it to support the relay of the Titan probe data. To facilitate the probe design studies, ESA and NASA have agreed to limit the probe entry velocity to the range 5.9-7.1 km/sec.

Figure 13-6. Titan probe targeting.

requirements constrain the flyby geometry during this initial Titan flyby. The flyby geometry must also serve to initiate the orbital tour, though, so some compromises may be required to optimize the science return from the Mission as a whole.
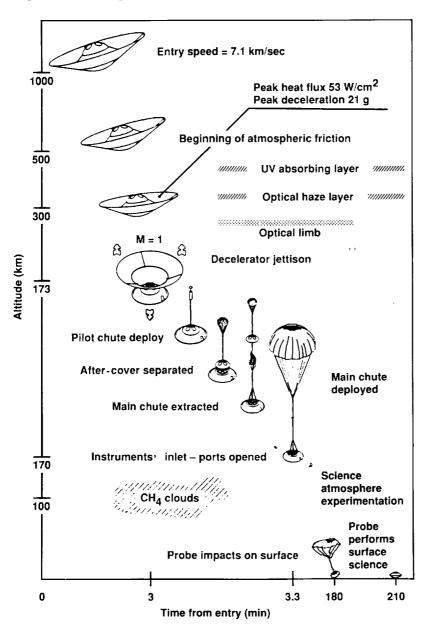
Figure 13-7 depicts the sequence of events that will take place during probe entry and descent. This sequence has been tailored to the Hunten-Lellouch model of the Titan atmosphere, which was previously described. The atmospheric entry interface is assumed to occur at an altitude of 1000 km; the probe will be designed to withstand an entry velocity of not more than 7.1 km/sec. The probe will descend and decelerate

rapidly, reaching peak deceleration at an altitude of 230-290 km. About 3 minutes after entry, the probe will reach Mach 1.5 and the large probe decelerator will be jettisoned, marking the end of the entry phase. The only instrument active during this phase will be the Atmospheric Structure Instrument; science and engineering data will be stored within the probe for later transmission to the orbiter.

The descent phase officially begins with deployment of the first parachute. This will occur at an altitude not lower than 170 km to ensure that the presumed region of methane clouds will be sampled. All science instruments will be active as soon as the main parachute is deployed and the inlet ports are opened (see fig. 13-7). The nominal probe descent time is 164 ± 10 minutes, from parachute deployment until surface impact. While Titan's zonal winds may displace the impact point by about 300 km, they will not appreciably affect the actual descent time. The impact velocity will be about 4-7 m/sec, which the probe should easily survive. If the post-impact attitude is favorable, transmission of data from the surface will be possible; in fact, the orbiter overflight will be designed to allow at least several minutes of post-impact data relay.

During atmospheric descent, science and engineering data are transmitted to the orbiter, which transmits the data in real time and also stores them for later replay. The probe antenna beamwidth of 120° has been chosen to account for uncertainties in the probe's location and attitude during the data relay. Assuming that the transmitted bit rate can increase in discrete steps as the probe-orbiter separation decreases, the total transmitted data should exceed 23 megabits if the orbiter flyby altitude is less than 2500 km. This takes into account uncertainties in the Titan environment models and the probe and orbiter trajectories, and assumes an optimized orbited overflight time. This also allows for about 5 minutes of post-impact transmission. Preliminary relay link design studies have identified the orbiter overflight time as a critical parameter; it is strongly coupled to the duration of the atmospheric descent including uncertainties. Therefore, it is important that Titan's atmosphere and surface be modeled as accurately as possible, so that the Probe Mission's scientific return can be maximized.
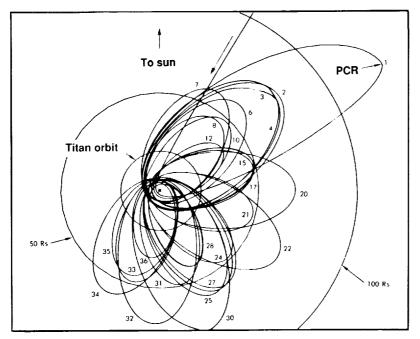
Figure 13-7. Titan probe descent scenario.

Figure 13-8. Cassini orbital tour: selected orbits.

Orbital Tour

The orbital tour phase of the Cassini Mission begins immediately after the relay of the Titan probe data and lasts until 4 years after the date of Saturn orbit insertion. The tour consists of a sequence of Saturn orbits connected by Titan gravity-assist flybys or small propulsive maneuvers; the size and orientation of these orbits is dictated by the various science requirements. Since Titan is the only Saturnian satellite massive enough to provide any appreciable gravity assist, almost every orbit must contain a Titan flyby. The tour of the Saturnian system will consist of about 40 Saturn orbits and Titan flybys; thus, there will be a great many opportunities for study of these two bodies, the "icy" satellites, the rings, the magnetosphere, and their mutual interactions.

Titan gravity assists are so effective in modifying the trajectory of a Saturn orbiter that many fundamentally different types of Saturn tours are possible; there is a great deal of freedom to choose the size, inclination, and orientation of each orbit to maximize the science return. While not every possible type of tour has been studied, there is a general tour strategy which appears to offer the most satisfactory compromise among the competing scientific objectives. A tour of this type has been adopted as the baseline for the purposes of mission assessment.
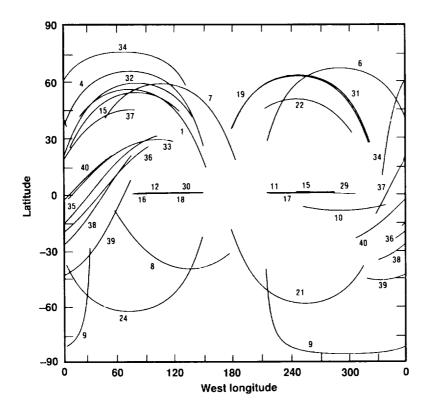
Figure 13-8 shows the sequence of Saturn orbits comprising the baseline Cassini tour, with respect to a fixed Sun-Saturn line. (Note that some orbits have been omitted for clarity.) Because the figure resembles a flower, each individual orbit is referred to as a "petal." The tour begins with the initial Titan flyby, immediately upon completion of the Probe Mission. The first two or three flybys are used to reduce the orbiter's period and inclination from the long-period insertion orbit to a low-inclination orbit with a period of about 30 days. Several flybys are then used to send the spacecraft behind Saturn as seen from Earth, so that radio signals and sunlight can be used to probe Saturn's atmosphere and rings. Following these occultations, a sequence of Titan flybys removes the

orbit inclination and rotates the orbit petal in the clockwise direction around Saturn. During this period, close flybys will likely be performed with Iapetus, Enceladus, and Dione.

As the orbit petal is rotated toward the anti-Sun direction, a second series of low-inclination orbits allows additional Saturn occultations, ring imaging, and a second close Iapetus flyby. The orbit is then rotated to establish the proper orientation for high-inclination Saturn occultations, and the last 10 or 12 Titan flybys are used to raise the inclination up to a final value of at least 80°. The orbital mechanics of the tour require that, as the inclination is raised, the orbital period must be reduced. The tour ends 4 years after Saturn orbit insertion, with the spacecraft in a high-inclination orbit with a period of 7.1 days.

Most of the approximately 40 Titan Flybys during a typical Cassini tour will occur at altitudes of 3000 km or less, and these are considered useful for the radar instrument. Figure 13-9 shows a trace of these flyby ground tracks on a map of Titan. While the Titan flyby geometry must be chosen primarily to produce the desired effect on the Saturn-centered orbit and to allow a free-return to Titan, it is likely that future tour iterations will focus more closely on optimized Titan surface coverage. There will be some trade-off as a Titan flyby is perturbed away from the optimum gravity-assist parameters to a geometry that maximizes Titan flyby science.

Figure 13-9. Titan ground tracks (altitudes below 3000 kilometers).

The baseline tour includes two close flybys of Iapetus and one each of Enceladus and Dione, and a total of 26 other "non-targeted" or accidental encounters within 100,000 km. The velocities of the icy satellite flybys range from about 3 km/sec for the targeted Iapetus flybys to over 20 km/sec for flybys of Mimas and Enceladus near the end of the tour. There are no close flybys of either Hyperion or Phoebe in the baseline tour. The non-targeted flybys sometimes occur only hours or minutes apart on any given orbit, so not all of the flybys will yield useful science.

Cassini Spacecraft System

Saturn Orbiter

The Saturn Orbiter will be the second in the series of Mariner Mark II (MMII) spacecraft, to be used for missions beyond the inner solar system. In keeping with the MMII design philosophy, these will be modular spacecraft that can be inexpensively reconfigured for different missions. Use of proven designs will be maximized; new technologies will be used only where cost effective and only if a viable backup is available. Data interfaces will use standard protocols and standard telemetry formats to minimize the impact of changes. Large margins in mass, power, and performance will be maintained to aid in cost control.

The Cassini spacecraft is illustrated in figure 13-10. At the top of the spacecraft is a 3.67-m diameter high-gain antenna (HGA) with a low-gain antenna (LGA) mounted at the top center. Below the HGA is a 10-bay bus where most of the electronics are stored.

The propulsion module subsystem (PMS) is dominated by two large conispherical bipropellant tanks. These will be of the same design as the tanks to be supplied for the Comet Rendezvous Asteroid Flyby Mission by the Federal Republic of Germany. Not visible in figure 13-10 are the small monopropellant tank which holds hydrazine for the reaction control system, the pressurant tank, and the 1.4-m radio antenna for the Titan probe data relay.

The spacecraft has three deployable appendages: two science booms and one boom for the radioisotope thermoelectric generators (RTGs), which will provide 600 watts of power at the beginning of the Mission. The magnetometer boom canister is located above the RTGs.
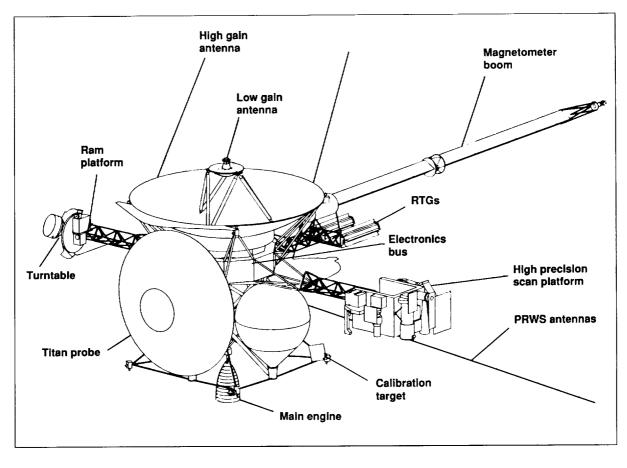
Figure 13-10. Cassini spacecraft configuration.

The high precision scan platform (HPSP) will provide two-axis pointing for the remote sensing instruments to an accuracy in inertial space of at least 2.0 milliradians, with pointing knowledge of 1.0 milliradians. The inertial reference unit and the star tracker will also be on the HPSP to maximize HPSP pointing accuracy. The HPSP motion is momentum compensated with reaction wheels mounted on the PMS. The turntable, located on a boom opposite the HPSP, will support the dust and particle analyzing instruments and will rotate continuously at 1 rpm. Also mounted on the turntable boom will be a platform to allow the aeronomy instruments to point in the direction of motion as the Titan flybys skim the upper atmosphere.

Transmission to and reception from Earth will be achieved with the 3.67-m diameter HGA (Voyager design), two LGAs, redundant 10.6-watt solid state amplifiers, Telemetry Modulation Units, transponders, and Command Detector Units. An LGA will be used for both uplink

reception and downlink transmission during periods when the HGA cannot point at Earth due to solar constraints and main engine burns, and in the event of an emergency during which HGA pointing is lost. Coverage on the ground will use the NASA Deep Space Network.

The three-axis stabilized spacecraft will be guided by a redundant inertial reference unit known as a Fiber Optics Rotation Sensor, which provides a gyroscopic function with no moving parts and which operates in conjunction with a star tracker and a sun sensor. The attitude control subsystem will control the pointing of the three science platforms and compensate for their motion, and will control the HGA pointing using a redundant reaction wheel assembly. In addition, the subsystem will control both the 400-N main engine gimbals and the 0.2-N reaction thrusters.
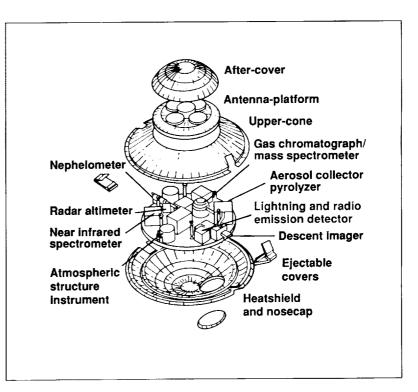
Two digital tape recorders (DTR) with a capacity of 1.8 gigabits each are on the baseline Cassini spacecraft, as are redundant solid-state buffers with a total capacity of 25 megabits. These random-access buffer memories will be used primarily to match data rates between the science instruments and the DTR, as well as between the DTR and the downlink.

Titan Probe

The Probe is currently subject to an industrial phase A study conducted by a European Industrial Consortium. This study will conclude in September 1988. A baseline system design has been developed to demonstrate that all science and mission objectives can be satisfied by a vehicle that will meet the Mariner Mark II interface requirements.

The probe is a blunt-nosed conical body with a half-cone nose angle of 60° and a nose radius of 1250 mm. The aerodynamic decelerator forms the afterpart of the thermal protection system and has an outer diameter of 3.1 meters. The aftercover protects the instruments from radiative heat transfer during descent; the decelerator and the aftercover will be jettisoned when the main parachute deploys. The heat shield is designed to tolerate an entry speed of not more than 7.1 km/sec. Figure 13-11 shows a sketch of the probe; not all details of this figure represent the latest configuration, but the general design concept is similar.

Figure 13-11. Titan probe configuration.

After-cover
Antenna-platform
Upper-cone
Gas chromatograph/ mass spectrometer
Aerosol collector pyrolyzer
Lightning and radio emission detector
Descent imager
Ejectable covers
Heatshield and nosecap
Nephelometer
Radar altimeter
Near infrared spectrometer
Atmospheric structure instrument

Conclusions

The Cassini Mission will address fundamental questions about the formation and evolution of the solar system, pre-biological organic chemistry, plasma physics, atmospheric dynamics, and virtually every other aspect of space science. Together with the Galileo Mission to Jupiter, it represents a systematic and comprehensive approach to the study of the outer planets.

Cassini is now moving toward a launch in 1996. As part of the Mariner Mark II program, Cassini is coupled with the Comet Rendezvous Asteroid Flyby Mission.

This allows a tremendous reduction in total costs for these two missions; together they provide complementary solutions to many critical pieces of a very complex puzzle. Cassini is a vital component of an exciting and coherent program of solar system exploration.

Additional Reading

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